Ocean Response Coastal Analysis System (ORCAS)

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Award Number: N00014-00-F-0080
http://www.onr.navy.mil/sci tech/ocean/onrpgahj.htm

LONG-TERM GOALS

Phytoplankton populations and communities respond to nutrient inputs on time scales from days to weeks. This short-term variability is superimposed on the long-term seasonal, annual and interannual variability in estuarine biogeochemical cycling that together regulate food web dynamics and ecosystem responses to nutrient loadings. Quantifying this short-term variability within the context of long-term changes in phytoplankton community structure (including harmful algal blooms), growth and production, relationship(s) to physico-chemical factors, food web efficiency and ecosystem ascendancy will provide critical information to assess nutrient thresholds for hypoxia and food web shifts. One of the long-term goals of the Gulf Ecology Division is to support EPA's efforts under the Clean Water Action Plan by establishing the scientific basis developing nutrient criteria for the Nation's coastal receiving waters.

OBJECTIVES

The primary objective is to determine the physiological responses and production dynamics of phytoplankton populations and communities, including harmful algal bloom species, in coastal waters and relationships to measures of environmental condition at similar temporal and spatial scales. The NOPP-ORCAS project is a collaboration between federal, academic, and private industry scientists centered around the technological development of a new system of autonomous, bottom-up moored profilers for coherent, real-time, high-resolution monitoring of multiple biological, physical, chemical, and optical parameters within the ocean in 3-D space and time. My role is to integrate, test, and deploy a Fastracka fast repetition rate fluorometer on the OCRAS array.

APPROACH

Alterations in nutrient loadings, including changes in the magnitude, ratio, and mode/timing of nutrient delivery to coastal receiving waters may alter the species composition of primary producer communities. Examples include development of harmful or nuisance algal blooms, shifts from benthic to pelagic production, and growth of benthic macroalgae at the expense of rooted aquatic vegetation. Such shifts are likely to cascade through the food web altering herbivore and higher trophic level communities, food web dynamics, and energy flow pathways in receiving waters. The resulting alteration in communities of primary producers may not support existing food webs, and hence may

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Ocean Response Coastal Analysis System (ORCAS)**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Environmental Protection Agency ,,National Health and Environmental Effects Research Laboratory,,Gulf Ecology Division,1 Sabine Island Drive,,Gulf Breeze,,FL,32561**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

lead to changes in the biological integrity of ecosystems with associated loss of commercially important fish and shellfish populations.

The ability to identify and quantify phytoplankton responses to environmental factors in situ requires knowledge of phytoplankton response parameters that can be monitored using in situ instrumentation and knowledge of how the parameter(s) respond(s) to the environmental stressor. Previous laboratory and field studies have demonstrated that algal abundance and growth responses are regulated by the availability of essential macro- and/or micronutrients, the result of physiological and molecular alterations in the cell that ultimately regulate photosynthesis and productivity. Such physiological responses in natural phytoplankton (including harmful algal bloom) populations and communities can be resolved and quantified in situ by real-time measurements of the variability in photosynthetic parameters using a fast repetition rate fluorescence techniques.

The approach is to identify and quantify photosynthetic responses to environmental factors in several HAB species and natural phytoplankton communities in Gulf of Mexico coastal waters using a Chelsea Instruments Fastracka fast repetition rate fluorometer. These efforts will quantify the variability in variable fluorescence yields (Fv/Fm), the absorption cross section of photosystem II (σ_{PSII}), and electron transfer kinetics as they relate to nutrient availability and flux, as well as other environmental conditions. Simultaneous measurements of optical properties will provide an opportunity to understand and relate changes in phytoplankton production to optical signatures. Laboratory enrichment studies will form the basis for understanding and interpretating phytoplankton photosynthesis responses in the field.

My other NOPP collaborators and their responsibilities are:

University of Rhode Island - Graduate School of Oceanography: Overall responsibility for NOPP-ORCAS project coordination, development and deployment of the ORCAS 4D profiling systems, the remote telecommunication network, physical, biological, optical data collection and analysis, subroutines for data processing, and dissemination.

WETLabs, Inc: Development optical sensors and intelligent controllers/loggers for profiling winches, sensors and analyzers.

SubChem Systems, Inc: *In situ* nutrient analyzers - development, field deployment, & data analysis. Assist URI with project coordination and logistics for field program

Naval Research Laboratory - Stennis Detachment: Coordination with Navy research optics programs, participation in mooring validation and diver exercises, data processing/ evaluation, algorithm development, transition of results to Navy. Provide a separate package measuring optical properties, to serve as the validation point for the mooring data. Serve as coordinator for the link between remote sensing and in-water optical measurements.

Commander, Naval Meteorology and Oceanography Command: Coordination with operational Navy objectives, provide divers for in-water visibility and vulnerability exercises, development and transition of operational product. Ship arrangements and costs.

WORK COMPLETED

Beginning in March 2001, efforts were initiated to collect weekly water samples from 1 m depth from a pier near the US EPA's Gulf Ecology Division Laboratory on Santa Rosa Sound (Florida, USA) to monitor temperature, salinity, ambient nutrients, total and size-fractionated phytoplankton biomass, and total and size-fractionated phytoplankton variable fluorescence. Beginning in April 2001, nutrient addition bioassays and phosphatase activity measurements were conducted 2 – 3 times per month in conjunction with the monitoring to complement information on phytoplankton physiological state provided by the variable fluorescence measurements. Dilution bioassays were conducted to assess the role of microzooplankton grazing on changes in phytoplankton size structure and to determine the influence of nutrient additions on gross growth rates of different phytoplankton size classes.

During September 10-28, ORCAS partners and support staff visited GED for the first field test of the ORCAS profilers. The field tests were conducted in shallow estuarine waters around GED and in the Gulf of Mexico aboard the RV Longhorn. These efforts included testing deployment and recovery, instrument performance, data communication links, data storage and visualization systems. We intended to deploy three types of instrument packages:

1. **Low-descent rate profilers** designed to be deployed from ships

2. **Micro profilers** and **Mini profilers** designed to be deployed from the bottom-up with real-time communication at the end of each cast.

3. **Maxi profiler** designed to be deployed from the bottom-up with continuous real-time communications and power through multiple cables to shore.

RESULTS

The nutrient addition bioassays suggest a shift from P to N limitation of phytoplankton growth near the end of the spring bloom. However, values of variable fluorescence yield (Fv/Fm) remained consistently high throughout the study suggesting little nutrient starvation despite apparent nutrient limitation of biomass accumulation. Addition of a nutrient cocktail (N, P, trace metals) to natural samples consistently resulted an increase in Fv/Fm and a decrease in σ_{PSII} and electron transfer kinetics. These results are consistent with the alleviation nutrient limitation in situ. During periods when the phytoplankton community appeared to be P-limited, bioassay additions of P resulted in increased Fv/Fm but had little effect on σ_{PSII} and electron transfer kinetics. During periods when the phytoplankton community appeared to be N-limited, bioassay additions of N resulted in decreased σ_{PSII} and electron transfer kinetics, but did not effect Fv/Fm. We have isolated into unialgal culture several phytoplankton species common to the Pensacola Bay/Santa Rosa Sound system. Laboratory nutrient studies and continued field monitoring and bioassays will provide a better understanding of phytoplankton physiological responses to nutrients.

IMPACT/APPLICATIONS

The technological development of ORCAS will be an important achievement to coastal monitoring and assessment approaches. The data and information generated from ORCAS may ultimately be used for developing early warning systems, nowcasting and forecasting, and predictive models of harmful algal

bloom development and transport, hypoxia, and other effects related to coastal nutrient enrichment. Imagine logging onto the internet from your home or office and accessing a web site (similar perhaps to the Weather Channel) that provided real-time information and forecasts on in situ environmental conditions in coastal waters.

TRANSITIONS

None to date

RELATED PROJECTS

Current research at EPA's Gulf Ecology Division provides methods, models, and data to support Agency efforts under the Clean Water Action Plan. Related research examines microbial, biochemical, and ecological dynamics in order to assess the effects of environmental stressors, such as excess nutrient loadings, on ecological resilience and sustainability. The ultimate goal is to provide the scientific basis for ecological criteria development.